[JP,2004-157677,A]

CLAIM + DETAILED DESCRIPTION

[Claim(s)]
[Claim 1]
The amount of jet of gas or a fluid, two or more squirters with an operational jet direction, a receptor that receives pressure with gas or a fluid which blows off from a squirter of this plurality, and a position of this receptor or this position and a means to measure a posture are provided,
Multi-flexibility drive mechanism carrying out feedback control of a position or this position, and a posture of said receptor by operating the amount of jet of said squirter, and its direction according to a desired value, a position of said measured receptor or this position, and a posture.
[Claim 2]
The multi-flexibility drive mechanism **** according to claim 1,
Multi-flexibility drive mechanism adjusting dynamic impedance of said receptor by changing a control gain of a system of said feedback control.
[Claim 3]
In Claim 1 or multi-flexibility drive mechanism given in either of 2,
Said squirter is an air squirter and said receptor is a wind receptor,
This air squirter in which directional control is possible is arranged at intervals of [three] 120 degrees on a plane inner circumference, Multi-flexibility drive mechanism, wherein said wind receptor is a cylindrical object which exists in an inside surrounded with said three air squirters, always controls a jet direction of said three air squirters centering on said cylindrical wind receptor and carries out feedback control of the position of 2 flexibility in a two-dimensional plane of said wind receptor.
[Claim 4]
In a virtual reality system using multi-flexibility drive mechanism given in either Claim 1, 2 or 3,
A virtual reality system having a virtual space display device which displays virtual environment artificially expressed inside a computer, being interlocked with a position or this position, and a posture of said receptor which were measured, and displaying a virtual object of said receptor in this virtual environment.
[Claim 5]
In the bar CHAKU reality system according to claim 4,
When a virtual object of a virtual body artificially expressed in said virtual space display device and said receptor contacts, A virtual reality system characterized by adjusting a desired value of mechanical impedance of a virtual object of said receptor, a position or this position, and a posture according to a movement state and dynamic impedance of said virtual body.

[Detailed Description of the Invention]
[0001]

[Field of the Invention]
It relates to the virtual reality system which presents virtual image space, this invention being accompanied by the inner force sense or a tactile sense using multi-flexibility drive mechanism and it.
[0002]
[Description of the Prior Art]
In recent years, the inner force sense presentation type virtual reality (VR) system for showing feeling which touches thing in the virtual space, and power feeling is developed by interlocking the multi-flexibility drive mechanism which is the real world, and the virtual picture which indicated it by imitation on virtual space. [for example the product called PHANTOM (http://www.nihonbinary.co.jp/Virtual/Phantom/)] Power feeling is shown by feeding back the calculated power to the stylus attached at the tip of two or more serial linkage mechanisms. The user can feel as if the form of the object in the virtual world which the computer made by touching the stylus, hardness, softness, a material feeling, etc. were genuine articles, looking at a virtual picture.
[0003]
[the function as the above-mentioned PHANTOM with same system called SPIDAR (http://sklab-www.pi.titech.ac.jp/detail/sdetail-j.html)] It is a system which adopts the tendon mechanism using two or more cables, and is realized.
[0004]
Since each of these drove the driver according to the transmission mechanism accompanied by mechanical contact, there was a fault of mechanism composition having become complicated and becoming the obstacle of free operation a user's hand.
[0005]
In view of such a problem, some this invention persons have proposed until now the device which presents power feeling without using a mechanical transmission mechanism by using wind pressure (patent documents 1).
[0006]
[Patent documents 1] JP,2001-22499,A.
[0007]
[Problem to be solved by the invention]
However, in this invention, since the utilization style which always holds a wind receptor by hand was assumed, when a hand was lifted, instability or the problem which becomes indefinite had a position of a wind receptor. Therefore, it was impossible to have realized the state where the virtual object of the wind receptor is made to stand it still in virtual space.
[0008]
The purpose of this invention is to provide the multi-flexibility drive mechanism which enabled it to control the position and posture of a receptor satisfactorily even if it lifted the hand, and raised the user-friendliness as a power presentation system.
[0009]
Another purpose is to provide the virtual reality system which raised power of expression by realizing the state of saying a receptor making it a motion of the corresponding object in virtual space interlocked with, and making it standing it still, or making it exercising.
[0010]
[Means for solving problem]

Two or more squirters in which an invention concerning Claim 1 has operational amount of jet and jet direction of gas or a fluid, A receptor which receives pressure with gas or a fluid which blows off from a squirter of this plurality, [by providing a position of this receptor or this position, and a means to measure a posture, and operating said amount of jet of said squirter, and its direction according to a desired value, a position of said measured receptor or this position, and a posture] It was considered as multi-flexibility drive mechanism carrying out feedback control of a position or this position, and a posture of said receptor.

[0011]

an invention concerning Claim 2 -- the multi-flexibility drive mechanism **** according to claim 1 -- it was considered as multi-flexibility drive mechanism adjusting dynamic impedance of said receptor by changing a control gain of a system of said feedback control.

[0012]

In Claim 1 or multi-flexibility drive mechanism given in either of 2, [an invention concerning Claim 3] Said squirter is an air squirter, said receptor is a wind receptor, and this air squirter in which directional control is possible is arranged at intervals of [three] 120 degrees on a plane inner circumference, Said wind receptor is a cylindrical object which exists in an inside surrounded with said three air squirters, A jet direction of said three air squirters was always controlled centering on said cylindrical wind receptor, and it was considered as multi-flexibility drive mechanism carrying out feedback control of the position of 2 flexibility in a two-dimensional plane of said wind receptor.

[0013]

In the virtual reality system by which the invention concerning Claim 4 used the multi-flexibility drive mechanism of the description for either Claim 1, 2 or 3, It was considered as the virtual reality system having a virtual space display device which displays the virtual environment artificially expressed inside a computer, being interlocked with the position or this position, and posture of said receptor which were measured, and displaying the virtual object of said receptor in this virtual environment.

[0014]

In the bar CHAKU reality system according to claim 4, [the invention concerning Claim 5] When the virtual object of the virtual body artificially expressed in said virtual space display device and said receptor contacts, According to the movement state and dynamic impedance of said virtual body, it was considered as the virtual reality system adjusting the desired value of the mechanical impedance of the virtual object of said receptor, a position or this position, and a posture.

[0015]

[Mode for carrying out the invention]

Although this invention gives pressure using fluids, such as water and oil, using gas, such as air and argon, and controls the position and posture of a receptor, it explains as an example the case where air pressure (wind pressure) is used, by the following explanation. In this case, a receptor turns into a wind receptor and a squirter turns into a wind squirter.

[0016]

In the form using wind pressure, even if the position and posture of a wind receptor are stabilized by wind pressure feedback control and it lifts a hand, the user-friendliness as a

power presentation system is raised by adding the function which controls the position and posture of a wind receptor satisfactorily.

[0017]

With Automatic Control Division are not by an operator's manual operation about a wind receptor, and according to an air actuator, By realizing the state of saying making it standing it still in virtual space, or making it exercising, the virtual reality system which was interlocked with the motion of the object in virtual space, changed the position and posture of the wind receptor, and raised power of expression is realized.

[0018]

First, the principle of the position control of the receptor of the 1 flexibility style by one pair of air squirters which is basic technology when realizing this invention is explained.

[0019]

Drawing 1 is a figure showing typically signs that position control of the wind receptor rigid body 3 which can operate on 1 straight line is carried out with the two air squirters 1 and 2 which oppose. In drawing 1, the position y of the wind receptor rigid body 3 presupposes that it is measurable in real time with the position sensing device 4.

[0020]

Although the power which the air squirters 1 and 2 give to the wind receptor rigid body 3 is generally expressed as nonlinear functions, such as compressed air pressure, distance, and nozzle dimensions, Below, for the simplification of an argument, the relation with the power f of generating the above-mentioned nonlinearity with the control input u of the air squirters 1 and 2 by linearization processing being performed by the disregard possibility of or a certain means near the control equilibrium point is assumed [that the usual transfer function G_w (s) can describe and], and advances an argument. And suppose that the disregarded influence is solved with the device of a feedback system design.

[0021]

In the case of the air squirters 1 and 2, the power f given to the wind receptor rigid body 3 aims to push and give wind pressure. for this reason, both positive/negative -- in order to control ****** 1 flexibility completely, the air squirters 1 and 2 of a pair put on the position which relative anti-carries out are needed. Thus, the problem which controls the position of a rigid body by the actuator which can take out only the power of one direction is called a uni-lateral actuator control problem, it appears in the case of the position control of many multi-flexibility drive mechanisms, such as a tendon mechanism, a magnetic levitation mechanism, and a robot hand, and an engineering design technique is existing. n+1 or more actuators are needed for generally controlling the rigid body of n flexibility, and, [the geometric arrangement] It is known that it is necessary to fulfill the conditions called form Closure or force closure (Journal of the Robotics Society of Japan Vol.13, No.7, and pp.56-63 basic theory of grip and manipulation).

[0022]

In drawing 1, assume for simplification that it is $G_w(s) = 1$, set to $f_2 >= 0$ power in which $f_1 >= 0$ and the left-hand side air squirter 2 generate the power which the right-hand side air squirter 1 generates, and, [as such difference] f**f_1-f_2 -- considering the new power f, the power of positive/negative both directions becomes operational in the range of $-f_1 <= f <= f_2$. When a feedback control system as shown in drawing 2 is given as the controller 5 there using PD compensation "$k_d s+k_p$" Becoming, transfer function W_{ry} from

the position desired value r to the position y of the wind receptor rigid body 3 is,

$$W_{ry}(s) = \frac{k_p}{ms^2 + k_d s + k_p}$$

It becomes. 6 in drawing 2 expresses an operation part, and 7 expresses wind receptor dynamics.

[0023]

However, mass of the wind receptor rigid body 3 was set to m, and the dynamics was made into $1/(ms^2)$. It turns out that the position control system which can be stable by setting a control gain as a suitable plus, and follows the position desired value r from this is realized. Although it cannot necessarily take greatly from a viewpoint of stabilization of the whole system by some nonlinearity which flattery nature becomes high so that a large control gain is generally taken, but is inherent in an air squirter, it can be coped with by giving a suitable stability margin.

[0024]

If transfer function W_{qy} from the external force (disturbance) q to the position y is calculated on the other hand,

$$W_{qy}(s) = \frac{1}{ms^2 + k_d s + k_p}$$

It becomes. Therefore, k_p is servo rigidity, and rigidity becomes large, so that this value is large. Similarly, k_d plays the role of the damper in a mechanical system, and viscosity becomes high, so that k_d is large. Thus, it turns out that it can set up freely by adjusting k_p and k_d suitably in the range which stabilizes the whole system, the Acknowledge, i.e., the mechanical impedance, to external force. It is possible to control the position y of the wind receptor rigid body 3 of 1 flexibility by the air squirters 1 and 2 of a pair put on the position which relative anti-carries out by the above-mentioned principle near the equilibrium point, and to set up the mechanical impedance freely with them.

[0025]

In this example, 1 flexibility becomes controllable similarly as the following by impressing fixed power, such as gravity, as bias force, for example instead of one air squirter. In drawing 1, since f can operate positive/negative both numerals in the range of $-f_1 <= f <= f_0$ supposing it gives fixed bias force as $f_0 > 0$ instead of the left-hand side air squirter 2 now, position control becomes possible by as same PD control law as the point within the limits of this.

[0026]

The embodiment which controls the position and posture of a wind receptor rigid body of many flexibility by below on the basis of the principle of the position control of the receptor rigid body of the 1 flexibility style explained above is described.

[0027]

This example embodies the multi-flexibility drive mechanism of the invention concerning Claim 3. Drawing 3 is a mimetic diagram of the mechanism which controls the cylindrical wind receptor rigid body 14 which has 2 flexibility on XY plane with the three air squirters 11, 12, and 13. The three air squirters 11, 12, and 13 are arranged on the circumference of radius r_0 left 120 degrees, respectively, It rotates to the circumference of the intersection of an air squirter thrust direction center line and the circumference, respectively, and has the angle controlling mechanisms (jet nozzle directional-control device: actuator) 11a, 12a, and 13a which can change a jet direction in XY plane. [by operating the amount of jet and jet direction of these three air squirters 11, 12, and 13] The wind pressure and the direction of the above-mentioned cylindrical wind receptor rigid body 14 are changed, and it explains concretely freely that it is possible to control the position on XY plane of the cylindrical wind receptor rigid body 14 below within the regular triangle which ties the air squirters 11, 12, and 13. If the biaxial sensor of rotation ball state etc. which are used with the mouse of the suitable image measuring means or the personal computer, for example are used, real time measurement is easily possible for the center position coordinates (x, y) of the cylindrical wind receptor rigid body 14.

[0028]

The fundamental view of control treats independently two control input called the jet direction and the amount of jet of the three squirters 11, 12, and 13, and is at the point which constitutes each feedback system gradually. That is, it will be the requisite to carry out real time control of the jet direction of the three air squirters 11, 12, and 13 first, so that it may always go to the center of the wind receptor rigid body 14.

[0029]

Drawing 4 is a figure showing typically the state where center O_w of the wind receptor rigid body 14 is located in the point (x, y) on XY coordinates. The following geometric relational expressions are drawn at this time. However, nozzle rotation angle $theta_1$, $theta_2$, and $theta_3$ determine a clockwise rotation as those for Masakata.

[0030]

$$\theta_1 = \tan^{-1}\left(\frac{x}{y - r_0}\right) \tag{1}$$

$$\theta_2 = \frac{\pi}{6} - \tan^{-1}\left(\frac{y + \frac{r_0}{2}}{x + \frac{\sqrt{3}}{2} r_0}\right) \tag{2}$$

$$\theta_3 = -\frac{\pi}{6} + \tan^{-1}\left(\frac{y + \frac{r_0}{2}}{-x + \frac{\sqrt{3}}{2} r_0}\right) \tag{3}$$

Therefore, since angle $theta_1$, $theta_2$, and $theta_3$ can be found if the center positions x and y of the cylindrical wind receptor rigid body 14 are measured, Next, jet direction control which makes this angle $theta_1$, $theta_2$, and $theta_3$ a desired value is realized by constituting a feedback control system like drawing 5. The operation part of a formula (1) and 16 express a PD controller, 17 expresses a nozzle rotation actuator (angle controlling mechanism 11a), and 15 expresses nozzle rotational movement dynamics 18. Although drawing 5 is about angle $theta_1$, it becomes a feedback control system with the same said of angle $theta_2$ and $theta_3$.

[0031]

The following relations are obtained from drawing 4 under a premise that this jet direction control is realized.

[0032]

$$\mathbf{f}_x = \mathbf{K}_w \mathbf{f}_w$$

ただし、

$\mathbf{f}_x = [f_x, f_y]^T$ ：直交座標上での円筒状風受容器剛体１４に加わる合力

$\mathbf{f}_w = [f_1, f_2, f_3]^T$ ：各空気噴出器１１、１２，１３が発生する力

アクチュエータ配置行列：$\mathbf{K}_w(\boldsymbol{\theta}) = \begin{bmatrix} -\sin\theta_1 & \cos\left(\frac{\pi}{6} - \theta_2\right) & -\cos\left(\frac{\pi}{6} + \theta_3\right) \\ -\cos\theta_1 & \sin\left(\frac{\pi}{6} - \theta_2\right) & \sin\left(\frac{\pi}{6} + \theta_3\right) \end{bmatrix}$

$\mathbf{x} = [x, y]^T$ ：円筒状風受容器剛体１４の中心位置座標（制御量）

$\boldsymbol{\theta} = [\theta_1, \theta_2, \theta_3]^T$ ：円筒状風受容器剛体１４の中心位置から計算される各ノズル回転角である。

[0033]

これらから、図６のようなフィードバック制御系を構成する。図６において、

$\mathbf{r}_x = [r_x, r_y]^T$ ：ｘの目標値

$\mathbf{e}_x = [e_x, e_y]^T$ ：ｘの目標値と現在地との差

$\mathbf{u}_x = [u_x, u_y]^T$ ：直交座標での操作量

$\mathbf{u}_w = [u_1, u_2, u_3]^T$ ：各空気噴出器の操作量

$\mathbf{K}_w^+ = \mathbf{K}_w^T (\mathbf{K}_w \mathbf{K}_w^T)^{-1}$ ：アクチュエータ配置行列$\mathbf{K}_w$の擬似逆行列

PD_x：Ｘ方向に関するＰＤ補償器（２１）

PD_y：Ｙ方向に関するＰＤ補償器（２２）

である。また、２３は演算部、２５は風受受容器ダイナミクスを表す。$\mathbf{u}_x$から$\mathbf{u}_w$への変換行列は無数に存在するが、疑似逆行列を設定することにより、トー

It is possible to minimize Tal's energy.

[0034]

It is possible to set up independently the kinematic control characteristics of the direction of X and the direction of Y by setting up PD_x and PD_y freely in consideration of the nonlinearity of an air squirter, interference of three winds, etc. here in the range in which the whole system is stabilized. For example, it is possible for the rigidity of the direction of X to be high and for the rigidity of the direction of Y to set up a proportional gain of PD_x low greatly, if a proportional gain of PD_y is set up small.

[0035]

In this example, 2 flexibility drive mechanism in which position control and arbitrary impedance setting are possible is realized at the arbitrary points inside the regular triangle which connects the angle controlling mechanisms 11a, 12a, and 13a of drawing 3 as mentioned above.

[0036]

Next, the method for carrying out virtual reality SHISUTEMUHE use for inner force sense presentation of this multi-flexibility drive mechanism about Claim 4 is explained using the above-mentioned embodiment.

[0037]

Drawing 7 shows the example which indicated the virtual object 31 of the cylindrical wind receptor by CG in the virtual screen of the virtual space display device expressing virtual space based on the measured value of the position (x, y) of the center which is a reference point of a cylindrical wind receptor. It is the restricted space where the space A has free space and the wall B has rigid k_b. For example, since power is not received from where of virtual environment, either, when the virtual object 31 of a cylindrical wind receptor exists in the inside of space A, without contacting the wall B, the feeling which drifts impedance in free space 0 or by setting up very small can be shown.

[0038]
When the virtual object 31 of a cylindrical wind receptor contacts the wall B, The impedance of the direction (transverse direction of drawing 7) of X receives for Masakata (right of drawing 7), sets to k_b, and in the negative direction of the direction of X, and the direction of Y, [0 or by setting up very small] the operator of a cylindrical wind receptor -- as -- real rigid k_b -- it becomes possible to give feeling which collided with the wall to a hand.
[0039]
That is, feeling while an operator looked at the object 21 of this virtual screen by the eye, as if the object actually existed there by moving a cylindrical wind receptor by hand can be given. Even if an operator lifts a hand in the middle of operation, an initial posture can maintain a wind receptor automatically. By using such a function, the animal which moves about in virtual space becomes possible [expressing impulse force when it collides with the vehicle by which the operator has ridden etc.].
[0040]
In the above explanation, although a case where a position of a wind receptor rigid body was controlled in a two-dimensional plane was explained, a position or a position, and a posture of a wind receptor rigid body are also controllable in three dimensional space. In this case, it is in a state which floated that wind receptor rigid body on space by making a wind receptor rigid body into right 6 face pieces, for example, and spraying a wind receptor rigid body of these six face pieces intensively using many air squirters, What is necessary is just to control a position and a posture of the wind receptor rigid body according to a motion of a corresponding object in virtual reality. An image measuring means can perform a position of a wind receptor rigid body in this case, and detection of a posture, for example.
[0041]
[Effect of the Invention]
The virtual reality display device which it is compact and is easy to use according to the feature of making gas and a fluid into motive power since it has the following advantages as multi-flexibility drive mechanism can be made from this invention. The transmission mechanism of the link which is interfered with, a wire, etc. by an interlude operationally alone Needlessness, Maintenance free and highly precise, since there are not correspondence possibility of and 6 mechanical friction in the design variation of devices, such as size change of 4 safety with three wide movable ranges which do not interfere with a background image display since it is not visible and transparent to eyes when using two winds, and 5 hardware, and a change in flexibility, flexibly.
[0042]
According to these features, virtual reality contents, such as a video game accompanied by the high power feeling of power of expression, are realizable by simple and compact hardware constitutions.
[0043]
It is carrying out real time control of the direction of three air squirters as a merit of the invention concerning especially Claim 3, so that it may always go centering on a wind receptor, and the following effects are born. 1 actuator arrangement procession: Since K_w (theta) serves as a function of only theta, and calculation of the false inverse matrix is simplified, a control law also becomes simple. Since the wind from 2 each air squirter

hits at right angles to the cylinder side of a cylindrical wind receptor, the influence of the power of the tangential direction serves as the minimum, since the influence of a mutual interference at the wind from each air squirter is also minimized, the modeling error of a controlled system also becomes small and a control system design becomes simple.

[Brief Description of the Drawings]

[Drawing 1]It is an explanatory view of the control model of straight line top 1 flexibility.

[Drawing 2]It is a block diagram of the air jet control system of 1 flexibility.

[Drawing 3]It is a mimetic diagram of a plane 2 flexibility control model.

[Drawing 4]It is an explanatory view of the coordinate system of a plane 2 flexibility control model.

[Drawing 5]It is a block diagram of the jet direction control system of the air squirter 11 of drawing 4.

[Drawing 6]It is a block diagram of the amount control system of air jet of a plane 2 flexibility control model.

[Drawing 7]It is an explanatory view of a virtual space display screen.

[Explanations of letters or numerals]

1, 2: Air squirter

3: Wind receptor

11, 12, 13: Air squirter,

11a, 12a, 13a: Angle controlling mechanism (jet nozzle directional control device)

14: Cylindrical wind receptor

31: Virtual object of cylindrical wind receptor

[Translation done.]